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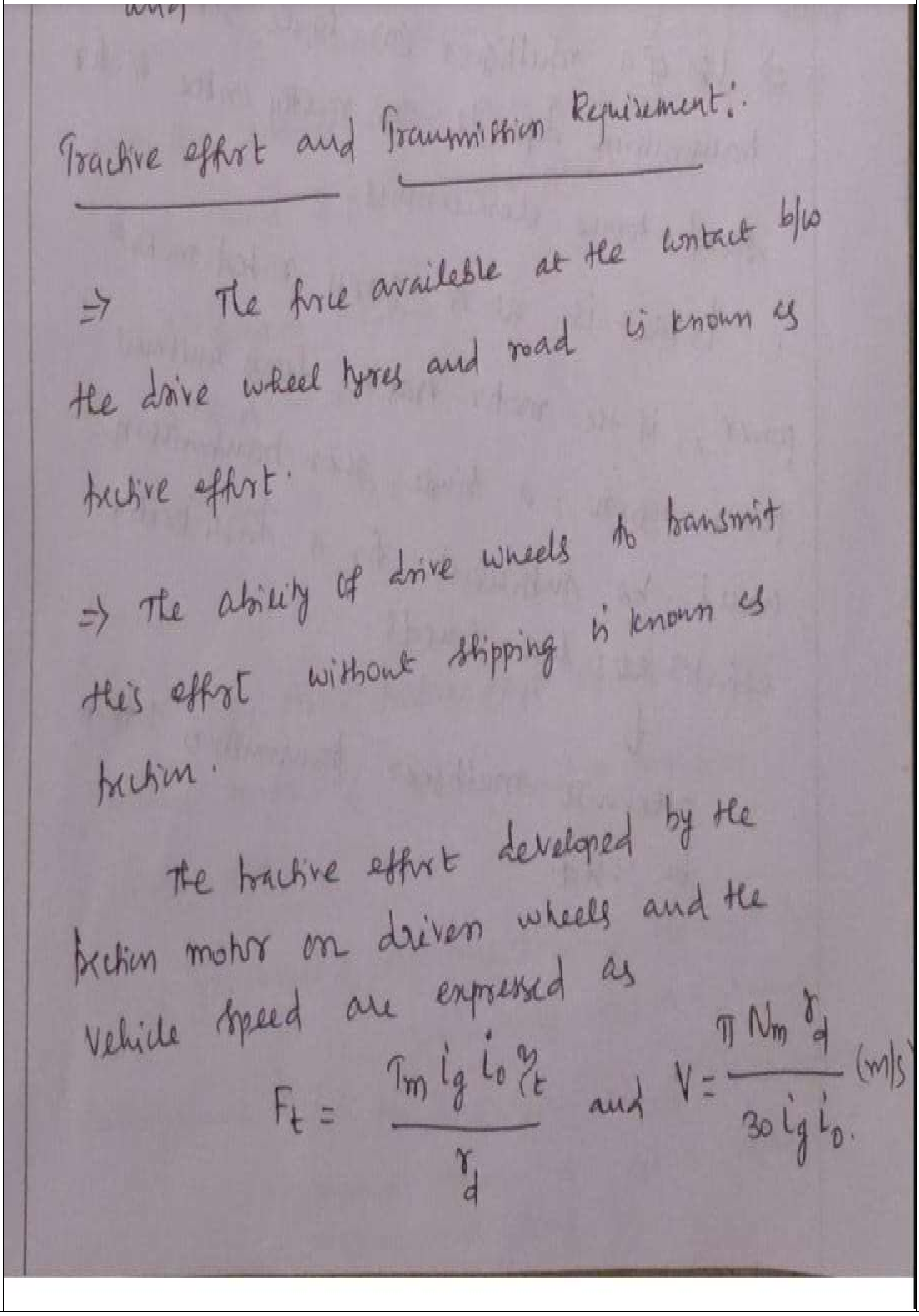
Internal Assessment Test - I

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sub: | **Electric Vehicles** | | | | | | | Code: | 21EE752 |
| Date: | 15/10/2024 | Duration: | 90 mins | Max Marks: | 50 | Sem: | 6th | Branch: | OE-ECE, CSE,AIML |

Answer Any FIVE FULL Questions

| | | Marks | OBE CO | OBE RBT |
|---|---|---|---|---|
| 1 | Explain in detail about Tractive effort and Transmission requirement. | 10 | CO2 | L2 |



Tractive effort and Transmission Requirement:

⇒ The force available at the contact b/w the drive wheel tyres and road is known as tractive effort.

⇒ The ability of drive wheels to transmit this effort without slipping is known as traction.

The tractive effort developed by the traction motor on driven wheels and the vehicle speed are expressed as

$$F_t = \frac{T_m i_g i_0 \eta_t}{r_d} \quad \text{and} \quad V = \frac{\pi N_m r_d}{30 i_g i_0} \text{ (m/s)}$$

$T_m$ - motor torque ~~in Nm~~

$N_m$ - motor speed in rps.

$i_g$ - is the gear ratio of transmission

$i_0$ - gear ratio of final drive

$\eta_t$ - Efficiency of the whole driveline to the driven wheels from the motor

$r_d$ - radius of the drive wheels.

⇒ Use of a multigear (or) single gear transmission depends on mostly on the motor speed - torque characteristics.

↳ that is at a given rated motor power, if the motor has a long constant power region, a single gear transmission would be sufficient for a high tractive effort at low speeds.

↓

otherwise multigear transmission has to be used.

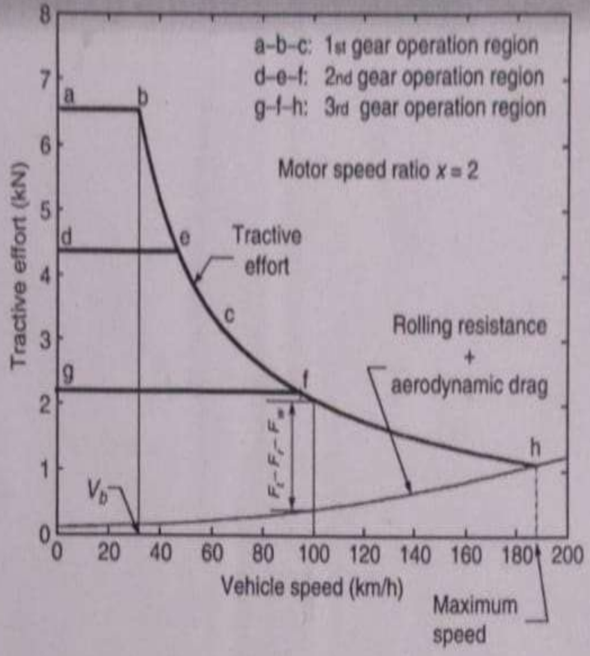


**Fig. 2.4: Tractive effort vs. vehicle speed with a traction motor of x =2 and three-gear transmission**

Above, fig. shows tractive effort of an EV, along with the vehicle speed with a traction motor of $x = 2$ and 3 gear transmission.

1st gear → a-b-c
2nd gear → d-e-f
3rd gear → g-f-g.

Below fig, shows tractive effort of an EV, with traction motor of $x = 4$ and a two gear transmission.

Rolling resistance → the force resisting the motion when body rolls on a surface.

Aerodynamic drag → the force of an object that resists its motion through a air is called aerodynamic drag.

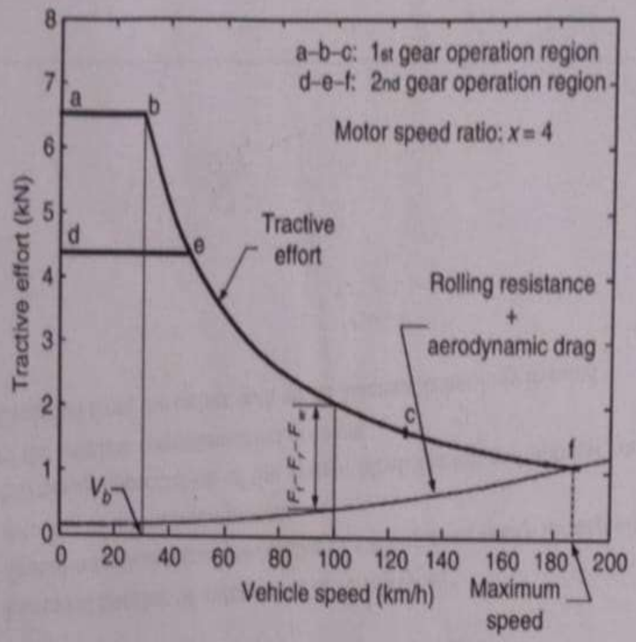


**Fig. 2.5: Tractive effort vs. vehicle speed with a traction motor of x=4 and two-gear transmission**

Above fig shows of $x=4$, and a two gear transmission.

First gear covers → a - b - c

Second gear covers → d - e - f

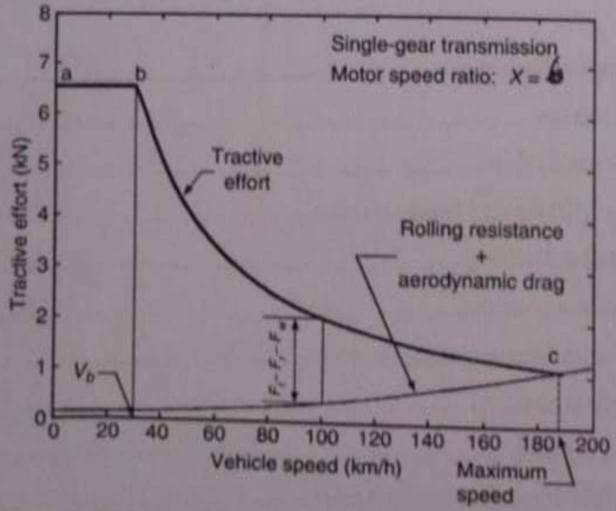


Fig: Tractive effort Vs Vehicle speed with a traction motor $x=6$ and ~~two~~ single gear transmission.

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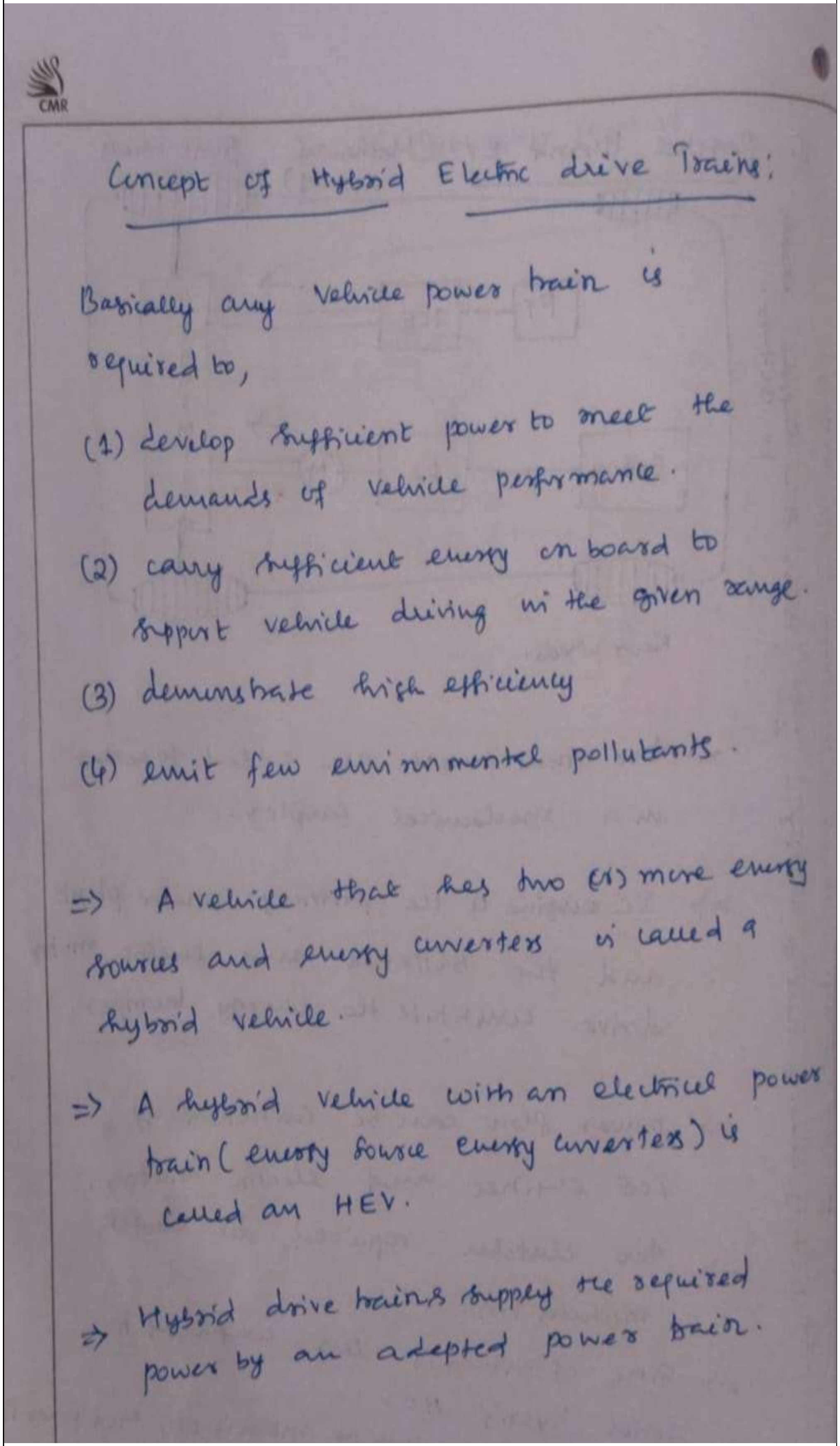
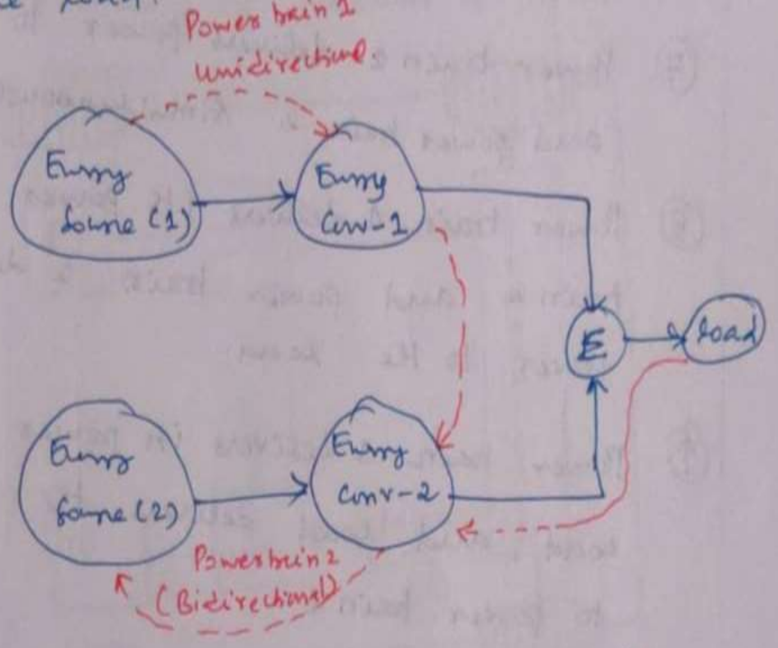
|---|---|---|---|---|
| 2 | Discuss the concept of Hybrid Electric Drive Trains and also list the HEV modes of operation.<br><br>Concept of Hybrid Electric drive Trains:<br>Basically any vehicle power train is required to,<br>(1) develop sufficient power to meet the demands of vehicle performance.<br>(2) carry sufficient energy on board to support vehicle driving in the given range.<br>(3) demonstrate high efficiency<br>(4) emit few environmental pollutants.<br>=> A vehicle that has two (or) more energy sources and energy converters is called a hybrid vehicle.<br>=> A hybrid vehicle with an electrical power train (energy source energy converter) is called an HEV.<br>=> Hybrid drive trains supply the required power by an adapted power train. | 10 | CO2 | L1 |

① Power train 1 alone develivers power to the load.



——→ Power flow while propelling

- - -→ Power flow hile charging power train (2)

② Power train 2 alone delivers its power to the load.

③ Both the power train 1 and 2 deliver their power to the load simultaneously.

④ Power train 2 obtains power from the load. (Regenerative braking)

⑤ Power train 2 obtains power ~~train 1~~ from power train 1.

⑥ Power train 2 obtains power from power train 1 and the load simultaneously.

⑦ Power train 1 delivers power to the load and power train 2 simultaneously.

⑧ Power train 1 delivers its power to power train 2 and power train 2 deliver its power to the load.

⑨ Power train 1 delivers its power to the load, and load delivers the power to power train 2.

## HEV Modes of operation:

- ⇒ Starting
- ⇒ Acceleration / Deceleration
- ⇒ Normal driving
- ⇒ Regenerative Braking
- ⇒ Battery charging while driving
- ⇒ Battery charging at standstill.
- ⇒ Axle balancing. (Complex HEV's)

| | | | | |
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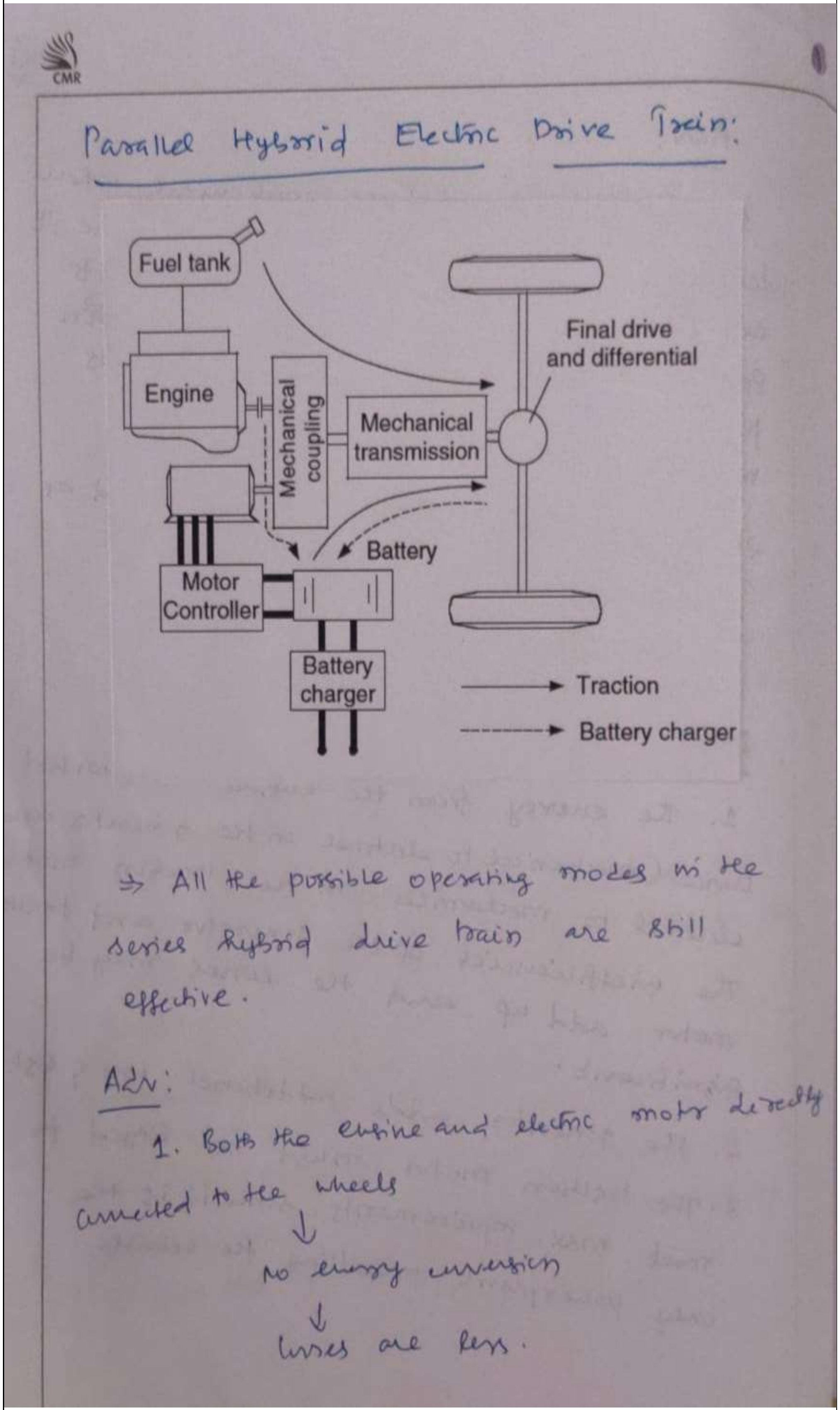
| 3 | Detailed explanations about Parallel Hybrid Electric Drive Trains with their merits and demerits. | 10 | CO2 | L1 |



Parallel Hybrid Electric Drive Train:

⇒ All the possible operating modes in the series hybrid drive train are still effective.

Adv:

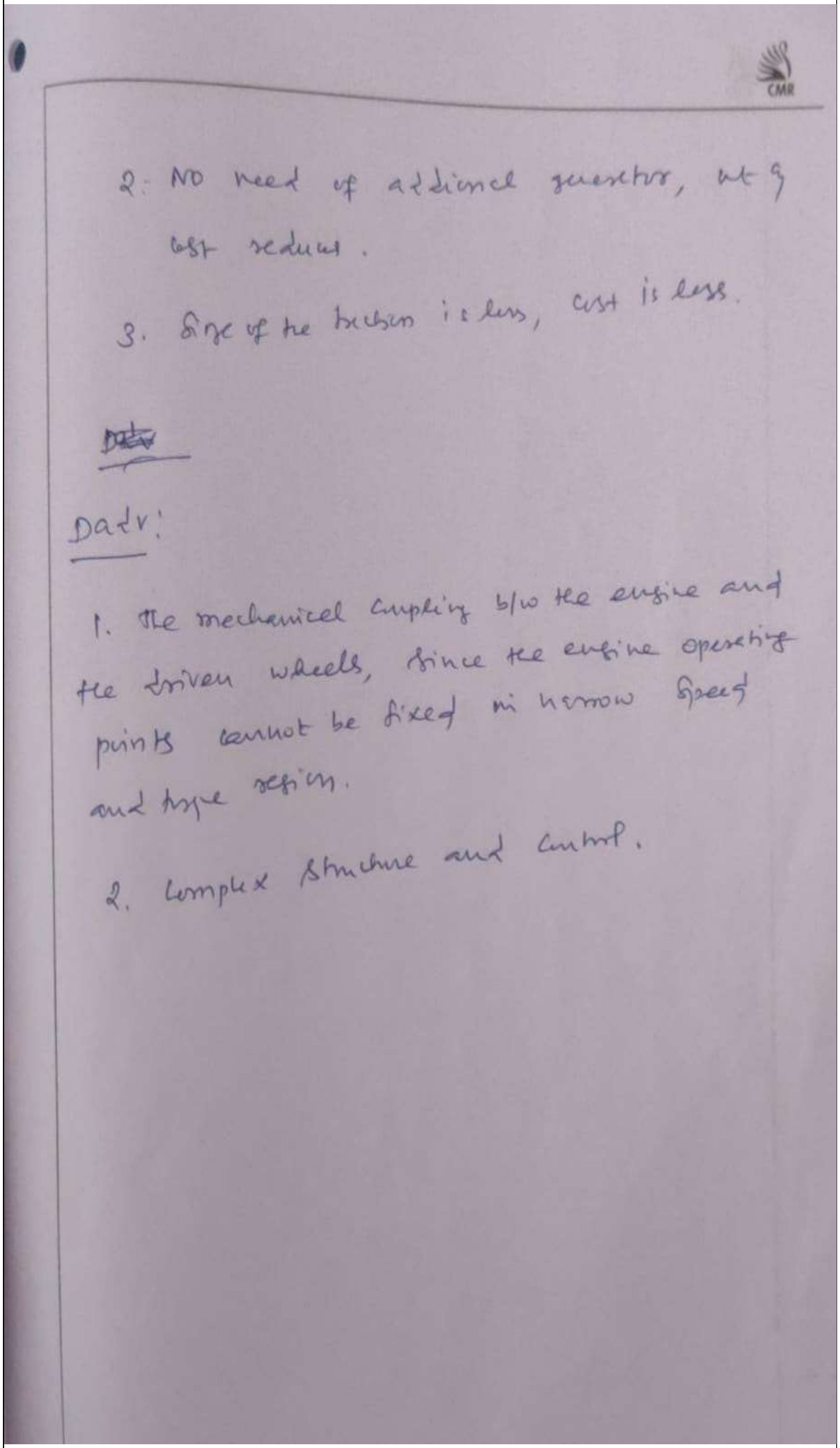
1. Both the engine and electric motor directly connected to the wheels

↓

No energy conversion

↓

losses are less.



2: No need of additional generator, wt & cost reduces.

3. Size of the traction is less, cost is less.

~~Dadv~~

Dadv:

1. The mechanical coupling b/w the engine and the driven wheels, since the engine operating points cannot be fixed in narrow speed and torque region.

2. Complex structure and control.

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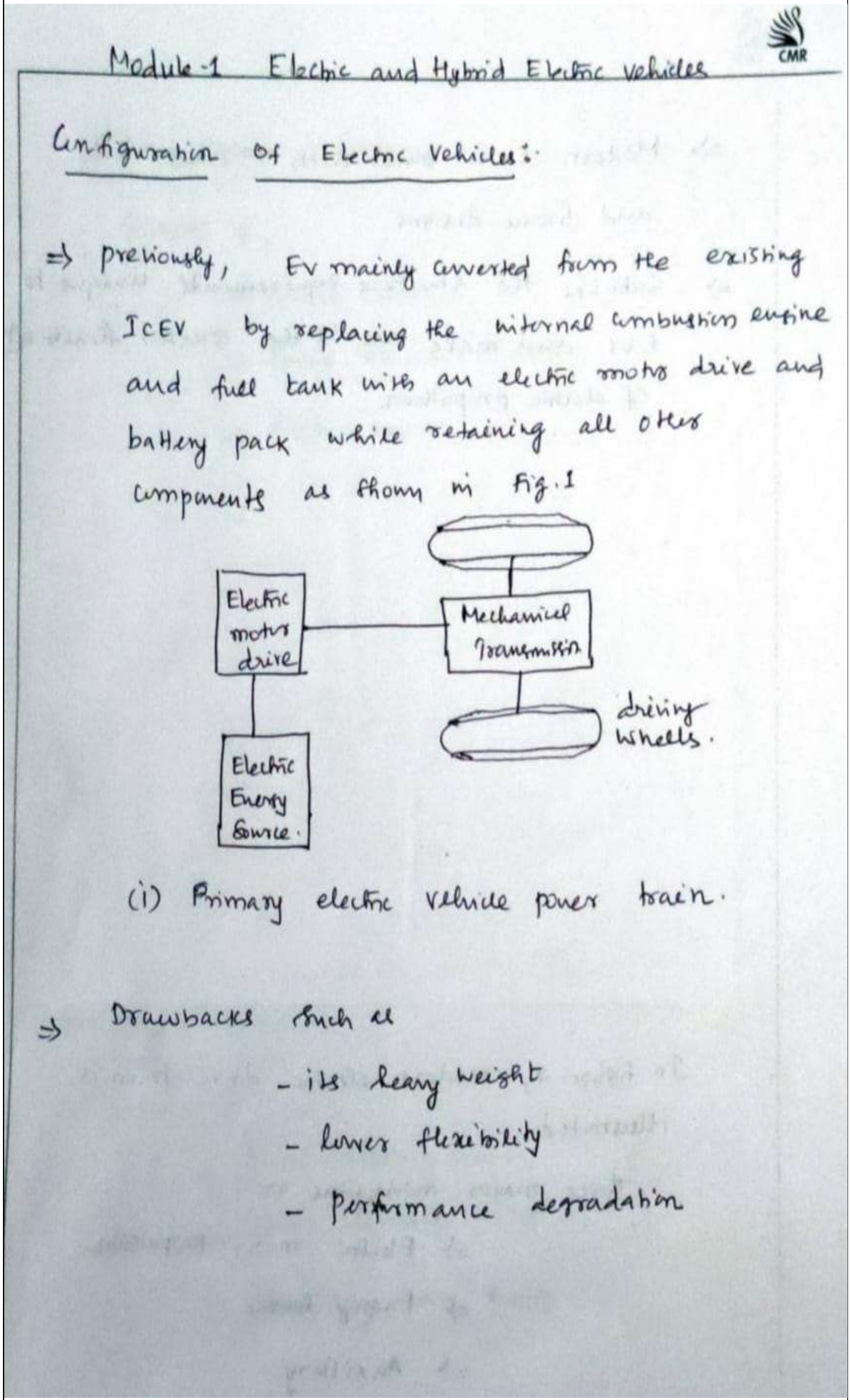
|---|---|---|---|---|
| 4 | Explain in detail about configuration of electric vehicles. | 10 | CO2 | L1 |



Module-1 Electric and Hybrid Electric vehicles

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## Configuration of Electric Vehicles:

⇒ previously, EV mainly converted from the existing ICEV by replacing the internal combustion engine and full tank with an electric motor drive and battery pack while retaining all other components as shown in Fig.1

(i) Primary electric vehicle power train.

⇒ Drawbacks such as

- its heavy weight
- lower flexibility
- Performance degradation

=> Modern EV is built with original body and frame designs.

=> Satisfies the structure requirements unique to EV's and make use of the greater flexibility of electric propulsion.

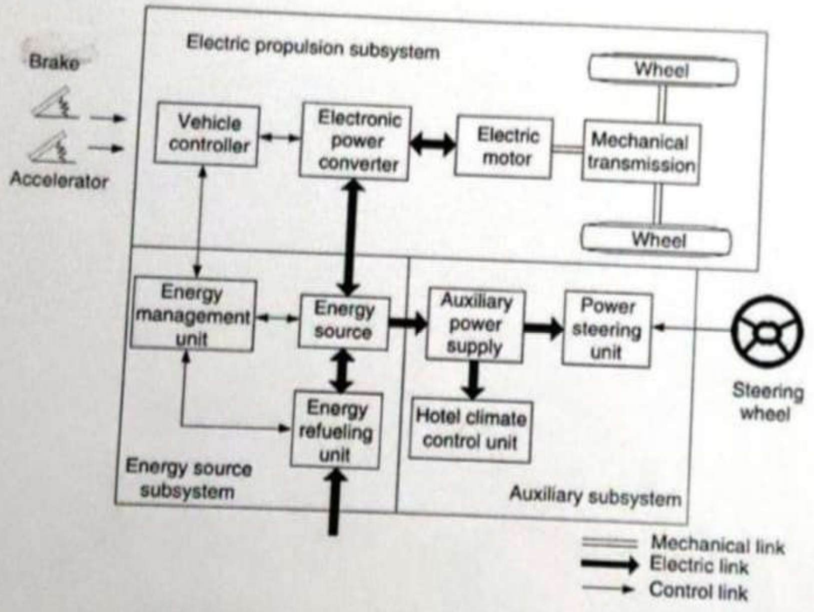


Fig. 2a Conceptual illustration of general EV configuration

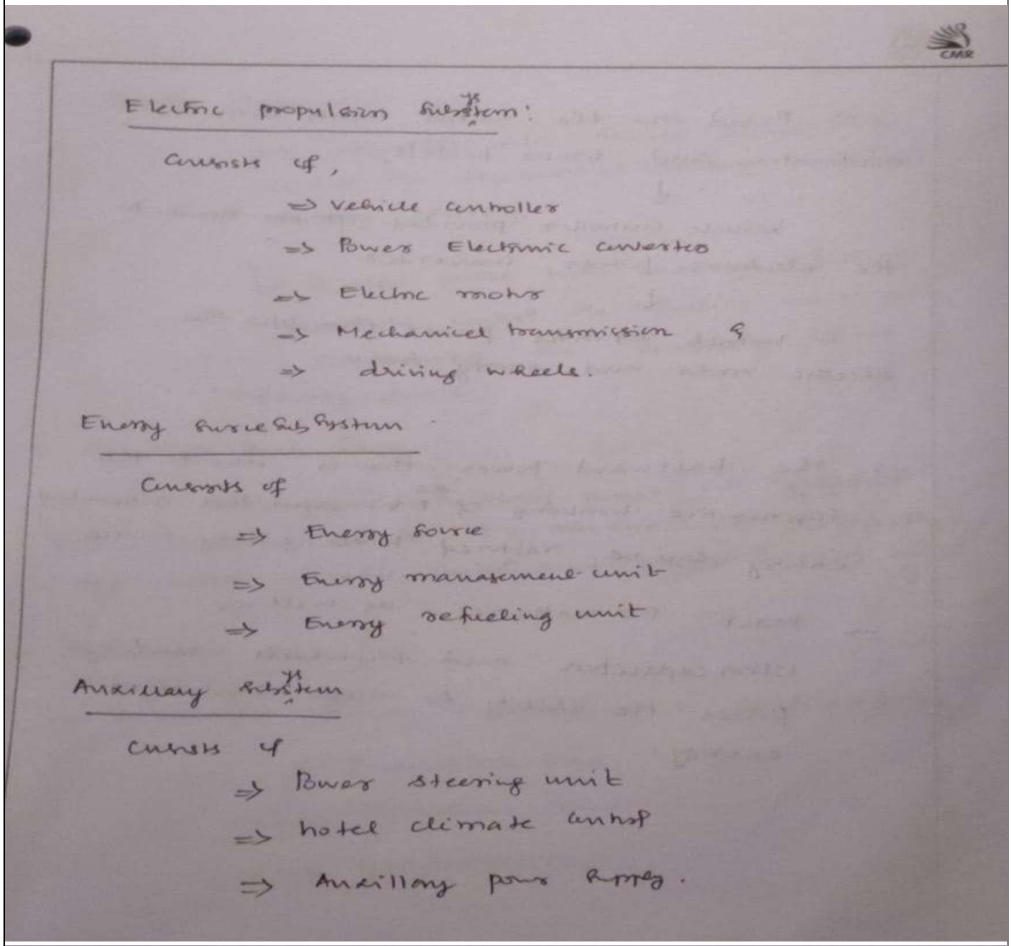
In figure 2, modern electric drive train is illustrated.

three major subsystems are

=> Electric motor propulsion

=> Energy source

=> Auxillary.



Electric propulsion subsystem:

Consists of,

=> Vehicle controller
=> Power Electronic converter
=> Electric motor
=> Mechanical transmission &
=> driving wheels.

Energy source subsystem

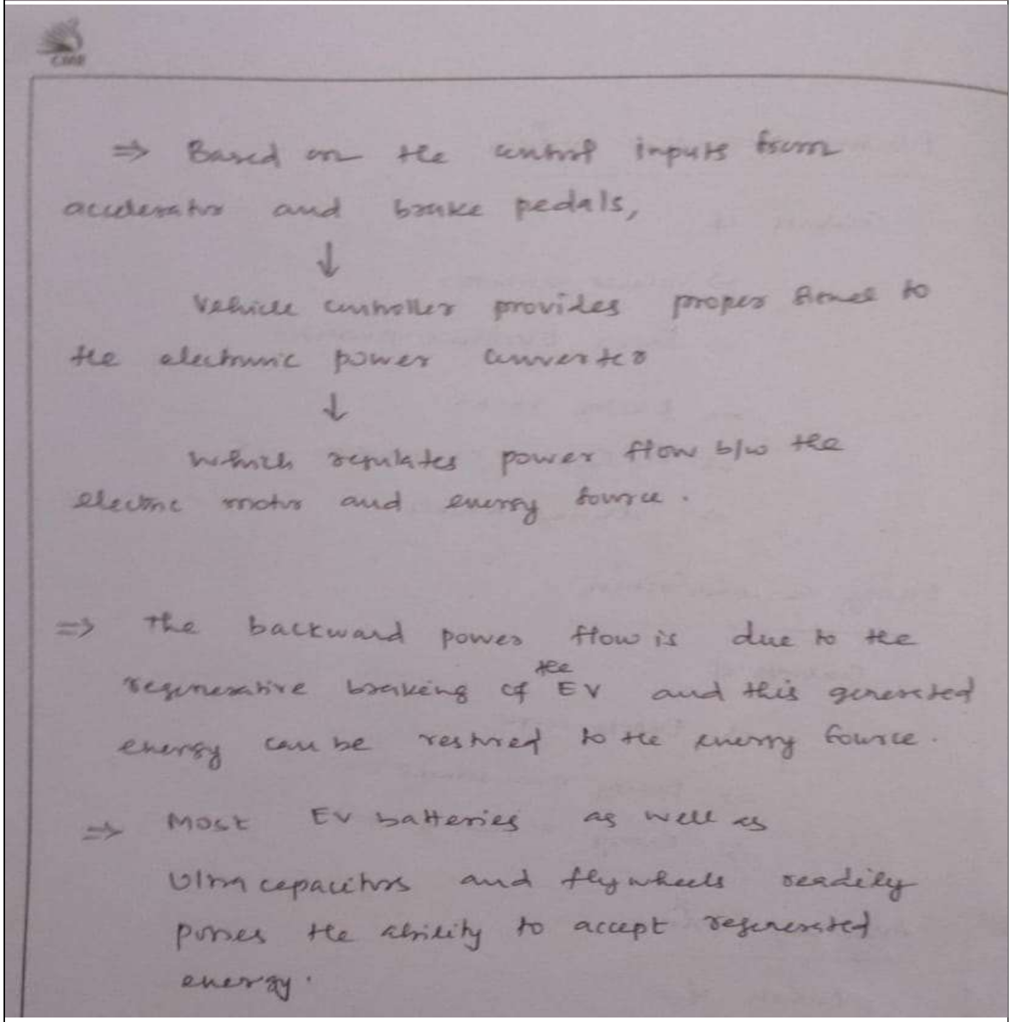
Consists of

=> Energy source
=> Energy management unit
=> Energy refueling unit

Auxiliary subsystem

Consists of

=> Power steering unit
=> hotel climate control
=> Auxillary power supply.



=> Based on the control inputs from accelerator and brake pedals,

↓

Vehicle controller provides proper signal to the electronic power converter

↓

which regulates power flow b/w the electric motor and energy source.

=> The backward power flow is due to the regenerative braking of the EV and this generated energy can be restored to the energy source.

=> Most EV batteries as well as ultracapacitors and flywheels readily posses the ability to accept regenerated energy.

Energy Management unit:

↳ Cooperates with vehicle controller to control the regenerative braking and its energy recovery.

↳ it also works with energy refueling unit to control the refueling unit and to monitor the usability of the energy source.

Auxillary Power Supply:

↳ provide necessary power at different voltage levels for all the EV auxillaries, especially the hotel climate control and power steering units.

## Performance of EV's

⇒ A vehicle's driving performance is evaluated by

(i) Acceleration time

(ii) Maximum Speed

(iii) gradeability.

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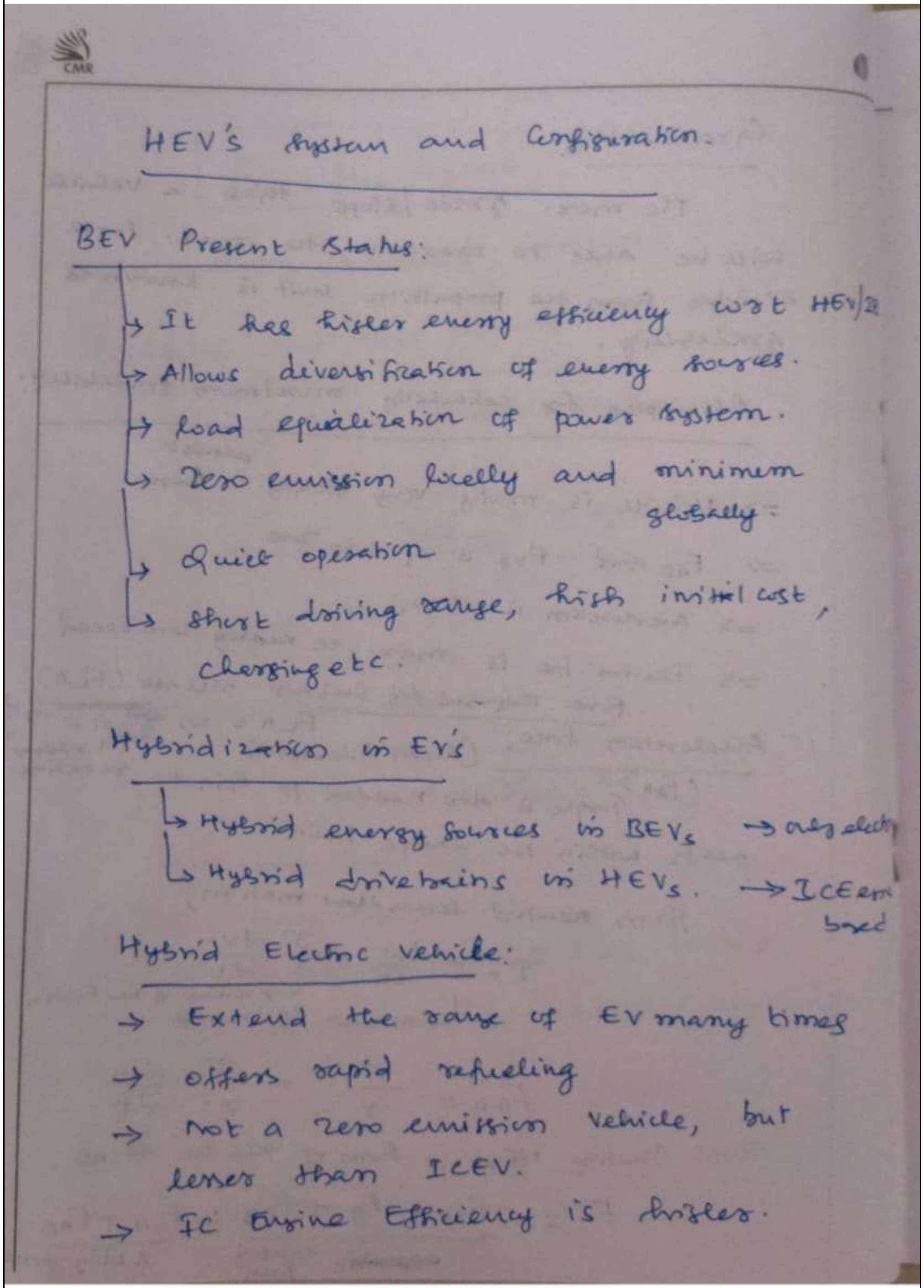
| 5 | Explain the architectures of Hybrid Electric drive trains.<br> | 10 | CO2 | L1 |

HEV's System and Configuration.

BEV Present Status:

- It has higher energy efficiency wrt HEVs
- Allows diversification of energy sources.
- Load equalization of power system.
- Zero emission locally and minimum globally.
- Quick operation
- Short driving range, high initial cost, charging etc.

Hybridization in EV's

- Hybrid energy sources in BEVs → only elect
- Hybrid drivetrains in HEVs. → ICEem based

Hybrid Electric vehicle:

→ Extend the range of EV many times

→ offers rapid refueling

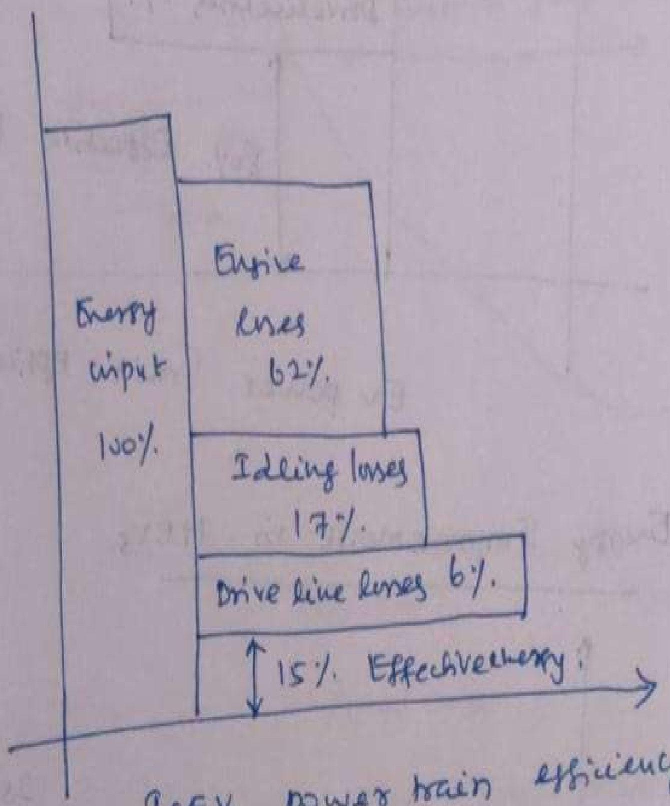
→ Not a zero emission vehicle, but lesser than ICEV.

→ FC Engine Efficiency is higher.

→ lower fuel consumption

→ Complex system.

## Vehicular Power train Efficiency in EVs and ICEV's

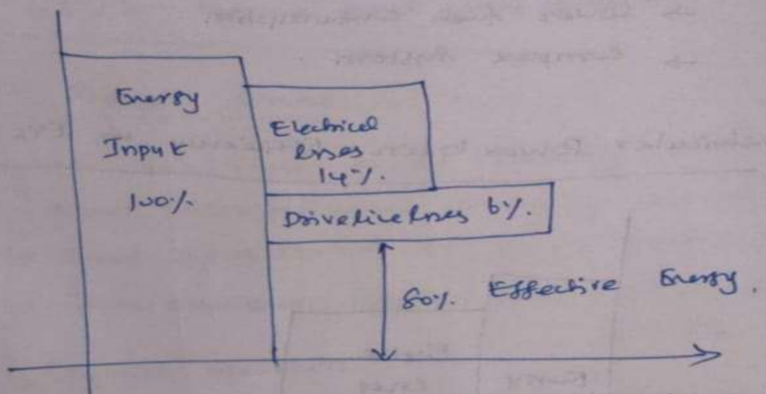


ICEV power train efficiency.

⇒ major loss as heat energy.

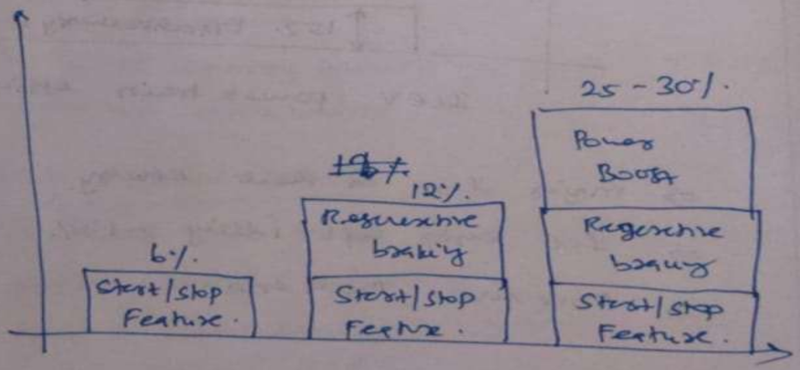
⇒ ICE engine left idling - 17%.

⇒ Drive line. mech loss.



EV power Train Efficiency.

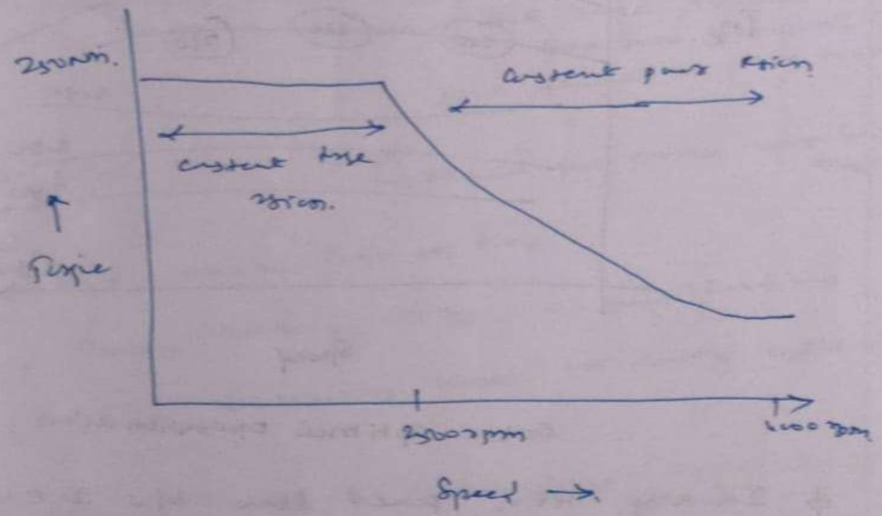
## Energy Improvement in HEVs



=> 30% energy efficiency is improved.

=> better efficiency for urban drive.

## Efficiency Map of typical EV electric motor.



=> Wide speed and torque ranges increase the maxi. speed.

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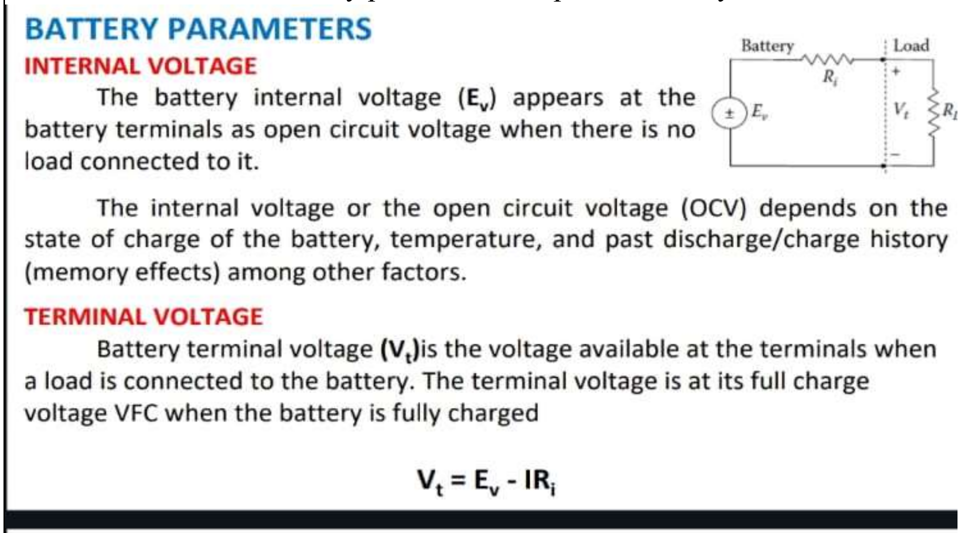
|---|---|---|---|---|
| 6 | What are the different battery parameters? Explain in briefly? | 10 | CO3 | L2 |



## BATTERY PARAMETERS

### INTERNAL VOLTAGE

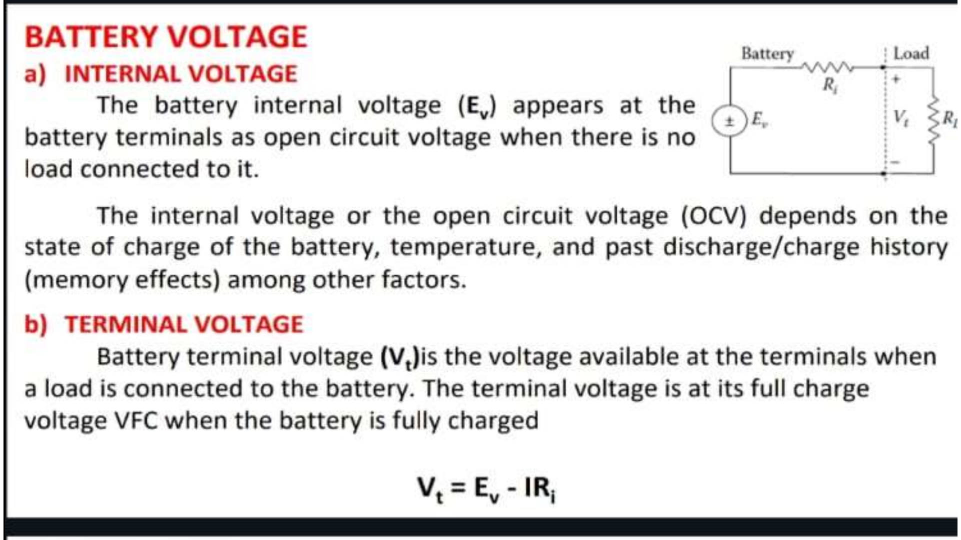
The battery internal voltage (**$E_v$**) appears at the battery terminals as open circuit voltage when there is no load connected to it.

The internal voltage or the open circuit voltage (OCV) depends on the state of charge of the battery, temperature, and past discharge/charge history (memory effects) among other factors.

### TERMINAL VOLTAGE

Battery terminal voltage **($V_t$)** is the voltage available at the terminals when a load is connected to the battery. The terminal voltage is at its full charge voltage VFC when the battery is fully charged

$$V_t = E_v - IR_i$$



## BATTERY VOLTAGE

### a) INTERNAL VOLTAGE

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### b) TERMINAL VOLTAGE

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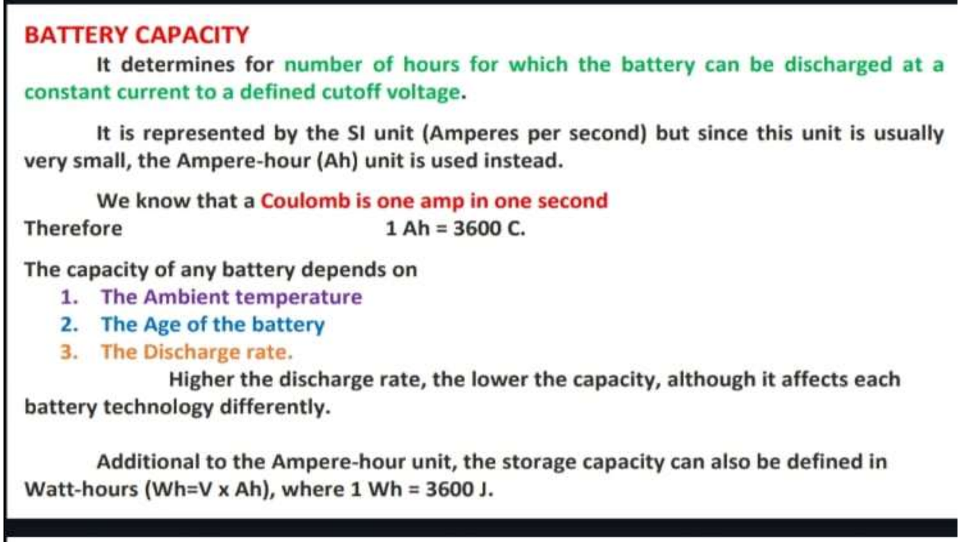


### BATTERY CAPACITY

**It determines for number of hours for which the battery can be discharged at a constant current to a defined cutoff voltage.**

**It is represented by the SI unit (Amperes per second) but since this unit is usually very small, the Ampere-hour (Ah) unit is used instead.**

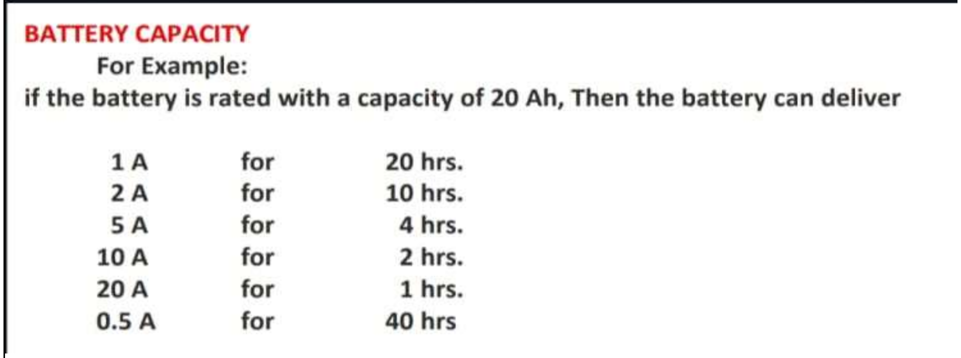
**We know that a Coulomb is one amp in one second**
**Therefore 1 Ah = 3600 C.**

**The capacity of any battery depends on**

1. **The Ambient temperature**
2. **The Age of the battery**
3. **The Discharge rate.**

**Higher the discharge rate, the lower the capacity, although it affects each battery technology differently.**

**Additional to the Ampere-hour unit, the storage capacity can also be defined in Watt-hours (Wh=V x Ah), where 1 Wh = 3600 J.**



### BATTERY CAPACITY

**For Example:**
**if the battery is rated with a capacity of 20 Ah, Then the battery can deliver**

| | | |
|---|---|---|
| **1 A** | **for** | **20 hrs.** |
| **2 A** | **for** | **10 hrs.** |
| **5 A** | **for** | **4 hrs.** |
| **10 A** | **for** | **2 hrs.** |
| **20 A** | **for** | **1 hrs.** |
| **0.5 A** | **for** | **40 hrs** |

## DISCHARGE RATE (C RATE)

It is a measure of the rate at which a battery is discharged relative to its maximum capacity. The notation to specify battery capacity in this way is written as $C_x$, where x is the time in hours that it takes to discharge the battery.

**For Example:**

If the capacity of a battery is C = 100 A h.

Then,

For a discharge rate of $\frac{C}{5}$ or $C_5$

The rate of discharge is $= \frac{100 \text{ Ah}}{5 \text{ h}} = 20\text{A}$

Similarly

For a discharge rate of $\frac{C}{0.5}$, 2C, $C_{0.5}$

The rate of discharge is $= \frac{100 \text{ Ah}}{0.5 \text{ h}} = 200\text{A}$

## STATE OF CHARGE (SOC)

The state of charge (SoC) represents the present capacity of the battery. It is the amount of capacity that remains after discharge from a top-of-charge condition

**For Example:**

It gives the ratio of the amount of energy presently stored in the battery to the nominal rated capacity.

For example,

If a battery is at 80% SOC and with a 500 Ah capacity, the energy stored (available) in the battery is 400 Ah.

### ENERGY EFFICIENCY

It is defined as the ratio of electrical energy supplied by a battery to the amount of electrical energy required to return it to the state before discharge.

### DEPTH OF DISCHARGE (DOD)

The depth of discharge (DoD) is the percentage of battery rated capacity to which a battery is discharged.

In many types of batteries, the full energy stored in the battery cannot be withdrawn (in other words, the battery cannot be fully discharged) without causing serious, and often irreparable damage to the battery.

The Depth of Discharge (DOD) of a battery determines the fraction of power that can be withdrawn from the battery. If the DOD of a battery is given by the manufacturer as 25%, then only 25% of the battery capacity can be used by the load.

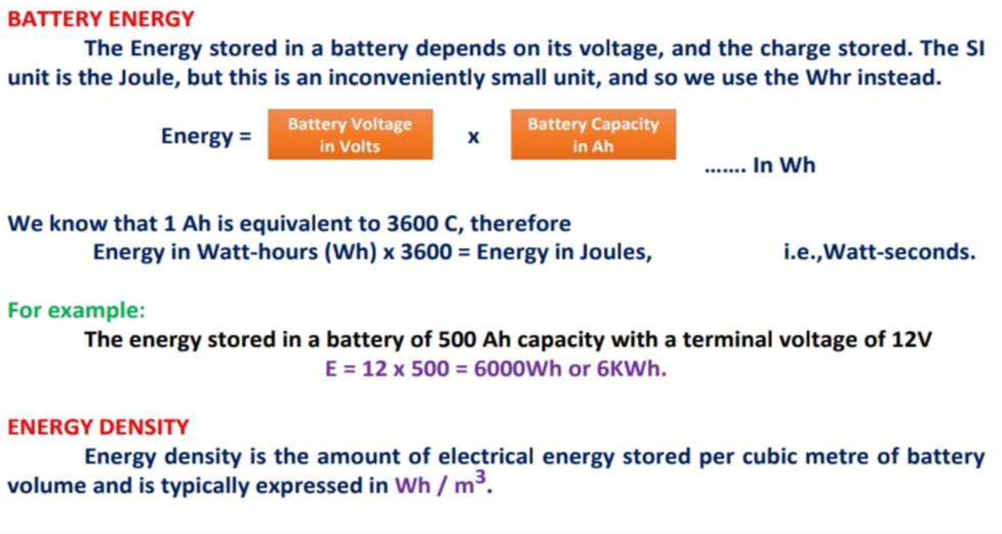
For example:

A battery of 500 Ah capacity with a DOD of 20% can only provide

500Ah x 0.2 = 100 Ah.

A battery of 500 Ah capacity with a DOD of 50% can only provide

500Ah x 0.5 = 250 Ah.



**BATTERY ENERGY**

The Energy stored in a battery depends on its voltage, and the charge stored. The SI unit is the Joule, but this is an inconveniently small unit, and so we use the Whr instead.

Energy = Battery Voltage in Volts x Battery Capacity in Ah ……. In Wh

We know that 1 Ah is equivalent to 3600 C, therefore

Energy in Watt-hours (Wh) x 3600 = Energy in Joules, i.e.,Watt-seconds.

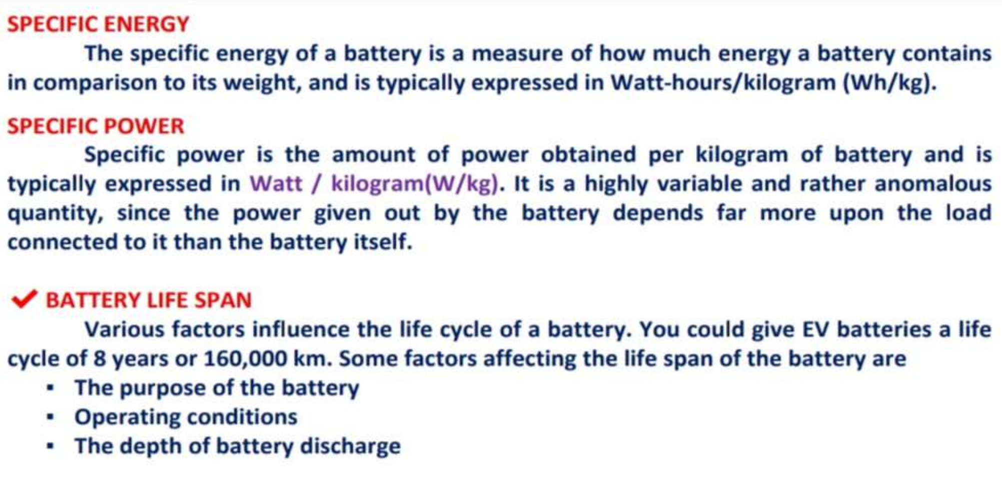
For example:

The energy stored in a battery of 500 Ah capacity with a terminal voltage of 12V

E = 12 x 500 = 6000Wh or 6KWh.

**ENERGY DENSITY**

Energy density is the amount of electrical energy stored per cubic metre of battery volume and is typically expressed in Wh / $m^3$.



**SPECIFIC ENERGY**

The specific energy of a battery is a measure of how much energy a battery contains in comparison to its weight, and is typically expressed in Watt-hours/kilogram (Wh/kg).

**SPECIFIC POWER**

Specific power is the amount of power obtained per kilogram of battery and is typically expressed in Watt / kilogram(W/kg). It is a highly variable and rather anomalous quantity, since the power given out by the battery depends far more upon the load connected to it than the battery itself.

✓ **BATTERY LIFE SPAN**

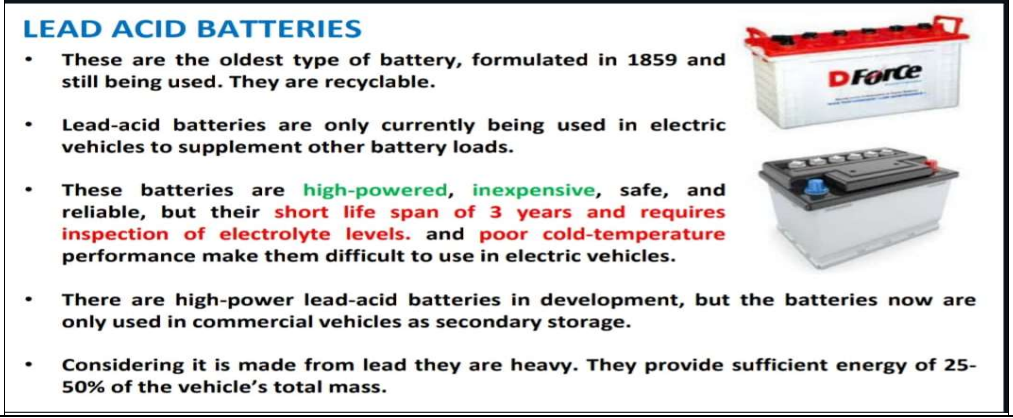
Various factors influence the life cycle of a battery. You could give EV batteries a life cycle of 8 years or 160,000 km. Some factors affecting the life span of the battery are

- The purpose of the battery
- Operating conditions
- The depth of battery discharge

| | | | | |
|---|---|---|---|---|
| 7 | Explain details about Lead acid and Lithium-ion batteries. | 10 | CO3 | L1 |

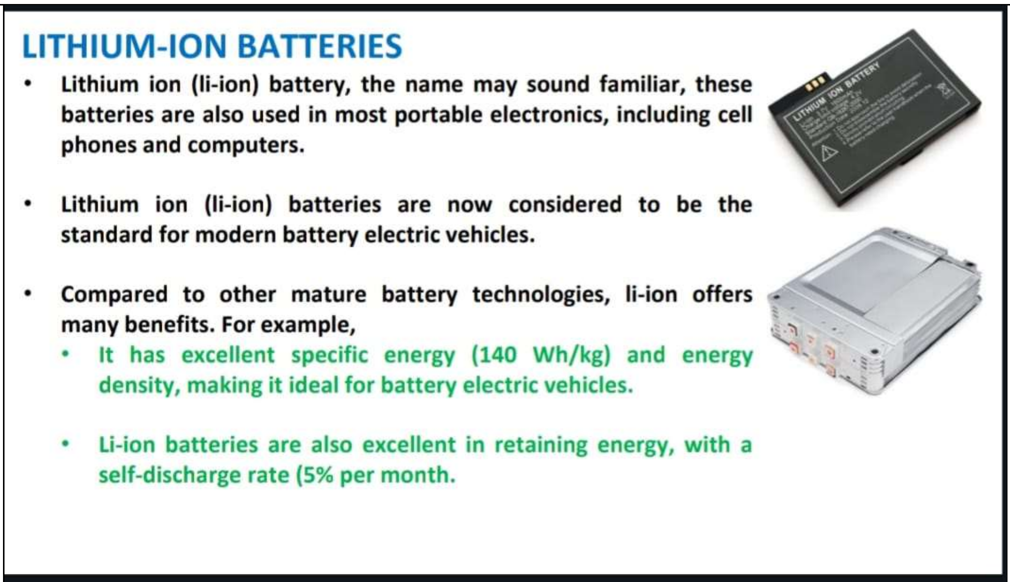
## TYPES OF BATTERIES USED IN EVs

- Lead-Acid Batteries
- Lithium-ion batteries
  - Lithium–Polymer (Li–P) Battery
  - Lithium-Ion (Li-Ion) Battery
- Nickel-based Batteries
  - Nickel/Iron System
  - Nickel/Cadmium System
  - Nickel-Metal Hydride (Ni-MH) Batt
- Ultracapacitors



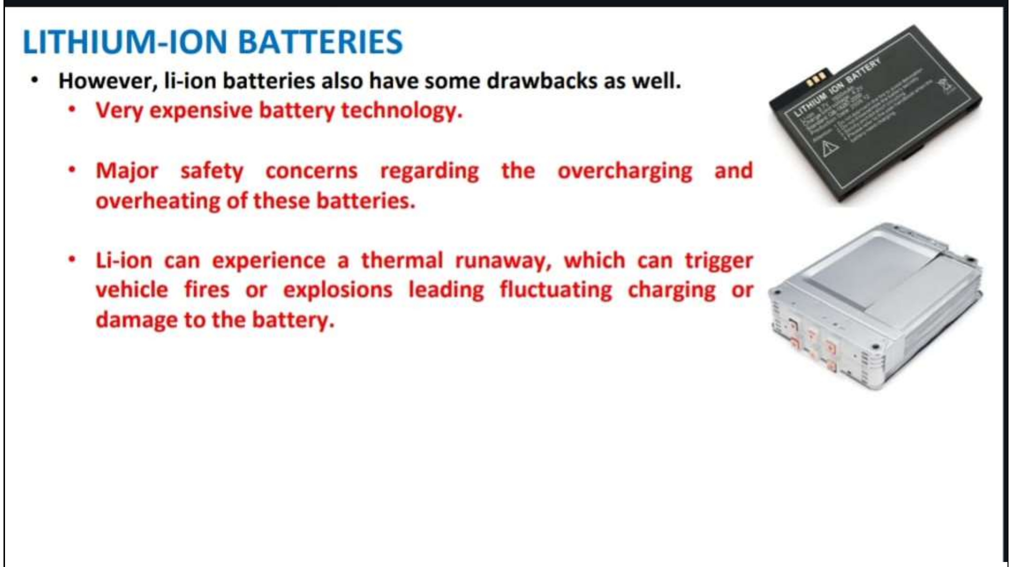
## LEAD ACID BATTERIES

- These are the oldest type of battery, formulated in 1859 and still being used. They are recyclable.
- Lead-acid batteries are only currently being used in electric vehicles to supplement other battery loads.
- These batteries are high-powered, inexpensive, safe, and reliable, but their short life span of 3 years and requires inspection of electrolyte levels. and poor cold-temperature performance make them difficult to use in electric vehicles.
- There are high-power lead-acid batteries in development, but the batteries now are only used in commercial vehicles as secondary storage.
- Considering it is made from lead they are heavy. They provide sufficient energy of 25-50% of the vehicle’s total mass.



### LITHIUM-ION BATTERIES

- Lithium ion (li-ion) battery, the name may sound familiar, these batteries are also used in most portable electronics, including cell phones and computers.
- Lithium ion (li-ion) batteries are now considered to be the standard for modern battery electric vehicles.
- Compared to other mature battery technologies, li-ion offers many benefits. For example,
  - It has excellent specific energy (140 Wh/kg) and energy density, making it ideal for battery electric vehicles.
  - Li-ion batteries are also excellent in retaining energy, with a self-discharge rate (5% per month.



### LITHIUM-ION BATTERIES

- However, li-ion batteries also have some drawbacks as well.
  - Very expensive battery technology.
  - Major safety concerns regarding the overcharging and overheating of these batteries.
  - Li-ion can experience a thermal runaway, which can trigger vehicle fires or explosions leading fluctuating charging or damage to the battery.

**CI** **CCI** **HOD**